7 Ground Anchors

Both the NFIP regulations (44 CFR 60.3) and the HUD *Model Manufactured Home Installation Standards* (24 CFR 3285.305) require that manufactured homes installed in flood-prone or SFHAs be anchored to resist flotation, collapse, or lateral movement.[1]

Ground anchors consist of a specific anchoring assembly designed to transfer home anchoring loads to the ground (24 CFR 3285.5). They are used extensively in manufactured home installations. Ground anchors are economical, readily available, and can be installed with relatively lightweight tools and equipment.

Ground anchors have potential limitations. One significant limitation arises from multiple soil-anchor response mechanisms as a function of soil type, anchor depth, and load configuration. Ground anchors have historically been allowed to move up to 3 inches horizontally or 2 inches vertically as the basis for determining acceptable performance. (Appendix E of the IRC established a ground anchor moving 2 inches in the direction of pull of the load as being acceptable.) When a manufactured home is secured with ground anchors, it too can move up to 3 inches when exposed to flood, wind, or seismic events.

Three inches of horizontal movement can produce eccentrically applied loads on piers under a home, which can cause the piers to topple and the home to collapse. Two inches of vertical movement can allow the home to lift and lose contact with the supporting piers. Unless the home is securely fastened to the piers and the piers constructed as monolithic units, the loss of contact can make the piers vulnerable to being displaced by moving floodwaters.

Ground anchor movements of several inches can have significant negative impacts on long-term performance. In cohesive soils, such anchor movements in a vertical direction can approach or exceed the soil's shear strength. In such cases, the ground anchor is supported by the soil's residual shear strength, resulting in a decrease in anchor capacity. In granular soils, large lateral movements may produce failure planes that can reduce the strength on the vertical direction.

Anchor assemblies, including ground anchors, should be inspected periodically, especially after hazard events. Loose anchor straps need to be retightened, and loose or failed anchors need to be reset or replaced. If movement has made the manufactured home structurally unstable, it should be reset to center it on its supporting piers. If this maintenance is not performed, the anchor assembly may fail during subsequent hazard events, resulting in significant damage to or destruction of the home. Tightening ground anchor straps typically costs a few hundred dollars or less. Replacing anchors or resetting a home is estimated to cost at least $1,000.

1 44 CFR 60.3(a), 44 CFR 60.3(b), and 24 CFR 3285.305 use the phrase "flotation, collapse or lateral movement." 44C FR 60.3(c) uses the phrase "flotation, collapse and lateral movement." To account for both usages, this publication uses "or."

7.1 Types of Anchors and Installed Configurations

7.1.1 Types of Anchors

Several styles of anchor assemblies are available that can adequately secure a manufactured home to resist flood, wind, and seismic forces. Helical earth anchors, cast-in-place concrete footings, drilled concrete anchors, and cross drive anchors are just a few of the types available.

7.1.1.1 Helical Earth Anchors

Helical earth anchors are designed to be augured (screwed) into the ground and are often referred to as ground anchors. Helical earth anchors typically consist of a shaft, head, and one or more helixes. The head is used for installing and fastening the anchor to the home, and tensioning the anchor. Toward the bottom of the shaft, there is one (single) or more helical disks for the anchor to be screwed into the soil. The helix provides much of the anchor's load capacity. The typical lengths of helical ground anchors are 30, 36, 48, and 60 inches.

Helical anchors also may be installed with stabilizer plates to increase the lateral capacity of the anchor by enlarging the surface area used to develop passive soil resistance.

7.1.1.2 Concrete Anchors

Concrete anchors use dead weight of a concrete footing or a combination of concrete weight and soil uplift resistance. Uplift resistance can be increased by the use of drilled concrete piers. In both cases, the home must be securely attached to the concrete elements using anchor bolts, tie-rods, or other structural connection. Anchor attachments placed in concrete must be installed with adequate depth to develop the required strength. The load capacity of the anchors must be sufficient to resist applicable design loads.

7.1.1.3 Cross Drive Anchors

Like helical ground anchors, cross drive anchors are constructed with a head secured to a metal shaft. Cross drive anchors are shafts driven into competent soils to develop their resistance. As their name implies, cross drive anchors are driven in pairs that form an "X" or cross (Figure 7-1). The heads of the anchors are secured to the home with metal straps.

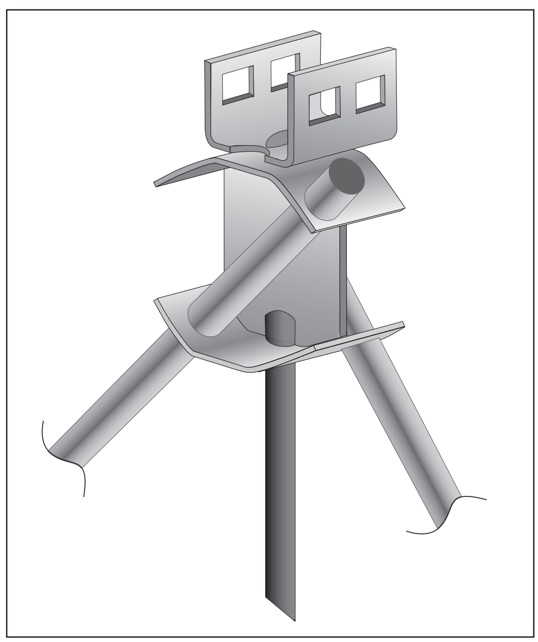


Figure 7-1. Cross drive anchor. (Courtesy of Tie Down Engineering)

7.1.2 Anchor Construction and Capacity

Steel ground anchors are the most common anchor assembly application for manufactured home installations. Ground anchors are typically constructed with a circular shaft of one or more helixes; a head connects at the opposite end of the anchor, which then connects to the home's frame and/or sidewalls with steel straps or cables. Anchor shafts are typically 5/8 inch to 3/4 inch in diameter, and helixes range from 3 inches to 8 inches in diameter. Most anchors used for manufactured home applications have one helix, although anchors with two to four helixes are available (Figure 7-2).

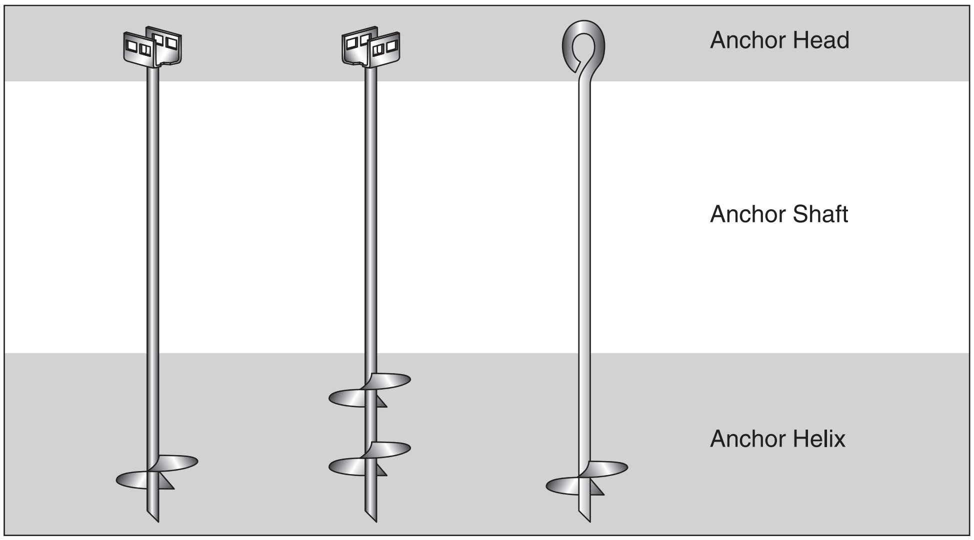


Figure 7-2. Single and double helix ground anchors with strap connection and single helix anchor with a closed-eye connection.

Most anchor heads are "U" shaped and contain predrilled bolt holes. The bolts connect the anchor to the home's frame or sidewalls with 1¼-inch anchor straps. Some anchors have heads with closed eyes for cable connections. The bolts in "U" shaped anchor heads can be used to pre-tension the anchor. Pre-tensioning an anchor with closed-eye heads requires using other devices like turnbuckles.

HUD requires anchoring equipment and anchoring assemblies to be capable of resisting allowable minimum working loads of 3,150 pounds and ultimate loads of 4,725 pounds without failure of either the anchoring equipment or the attachment point on the manufactured home.

7.1.3 Anchor Selection

Ground anchors should be selected based on the specific soils conditions at the manufactured home site. Short anchors with smaller helixes may be used in firm, well compacted soils. Longer anchors or anchors with larger or multiple helixes are required in weaker soils.

Most anchors are selected based on standard torque probe tests conducted at the site. During those tests, a 5-foot long auger probe is screwed into the ground to the approximate depth of the anchor helix. A torque wrench measures the torque required to advance the probe. The resulting torque value is used to classify the soils and select an appropriate anchor based on recommendations of the anchor manufacturers. Table 7-1 depicts how one anchor manufacturer classifies soils for anchor selection.

Table 7-1. Soil Classifications Using a Standard Torque Probe (STP)

Soil Class	Test Value (in. lbs.)	Soil Description
1	N/A	Sound hard rock.
2	550+	Very dense and/or cemented sands, coarse gravel, cobbles, preloaded silts, clays, and coral.
3	350 to 550	Medium dense coarse sands, sandy gravels, very stiff silts and clays.
4a	275 to 350	Loose to medium dense sands, firm to stiff clays and silts, alluvial fill.
4b	175* to 275	Loose sands, firm clays and silts, alluvial fill.

*Below 175 in. lbs. a professional engineer should be consulted

7.1.4 Anchor Installation

Anchors can be machine-installed or hand-installed. Machine installation involves using portable torque equipment to rotate and advance the anchors into the supporting soils. Figure 7-3 shows an electric installation device, also known as a portable anchor drive machine.

Figure 7-3. Electric anchor drive machine. (Courtesy of Tie Down Engineering)

Hand installation involves excavating holes for the anchors, placing the anchors into the holes, and then backfilling and compacting the removed soil. Hand installation disturbs significantly more soil than machine installation and reduces anchor load capacity. Manufacturers typically limit the depth of pre-drilling to two-thirds the anchor length. They also recommend against hand installations in areas with poor soils.

Anchors are typically installed vertically or inclined slightly from vertical to facilitate installation. Typical inclinations range from approximately 5 to 15 degrees from vertical. Where required, stabilizer plates are installed adjacent to the anchor shaft (Figure 7-4). This allows anchors to be installed after the manufactured home is positioned and locates the exposed anchor heads behind the manufactured home's skirting. Anchor straps are then installed to the manufactured home frames and, in HUD Wind Zones II and III, to the wall ties installed when the home is fabricated. When used in this configuration, stabilizer plates are installed to provide additional lateral resistance for the anchor assembly.

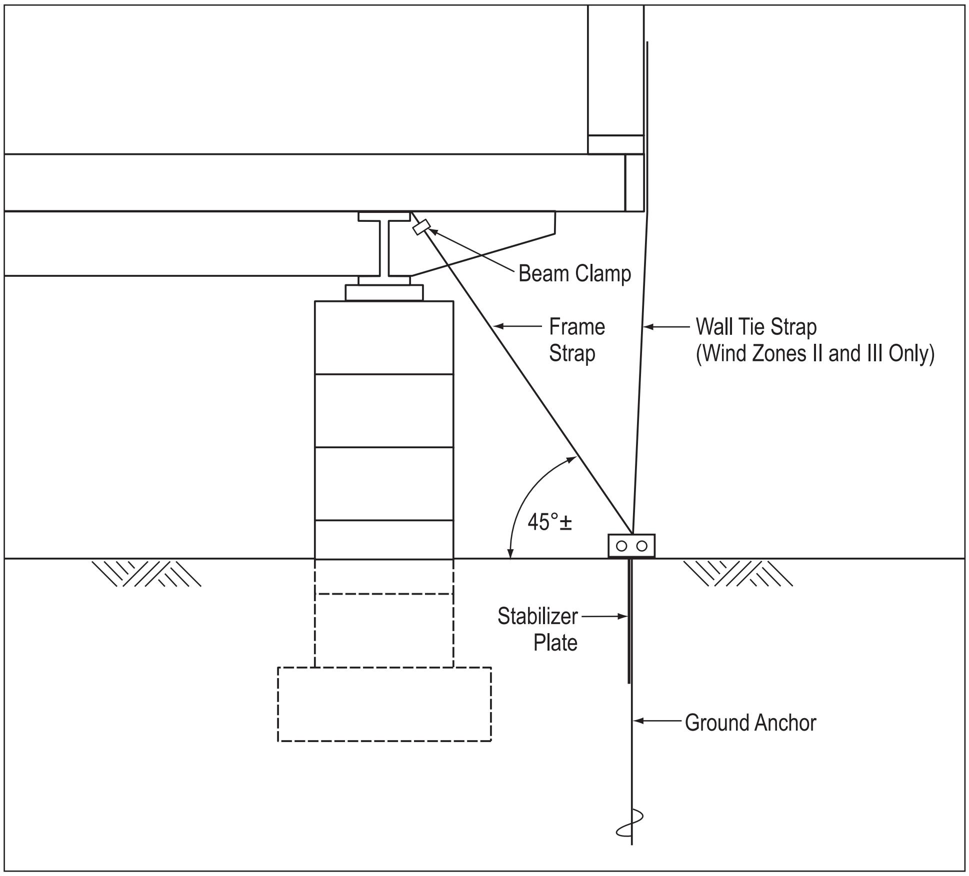


Figure 7-4. Typical ground anchor installation.

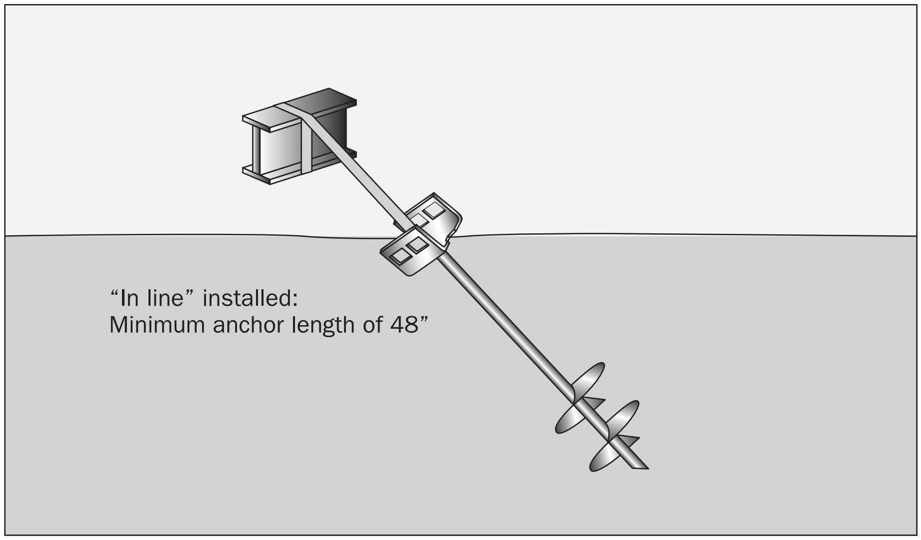
When fastened as vertical wall ties and loaded axially, ground anchors may be used without stabilizer plates. When ground anchors are used with some proprietary foundation systems, anchors can be installed 45 degrees to the horizontal and loaded axially (Figure 7-5).

7.1.5 Anchor Performance

The capacity of anchoring systems is a function of the soil response to loads applied to the anchor assembly. For ground anchors, important geotechnical considerations include soil type or classification, soil shear strength, load-deformation characteristics (i.e., modulus of subgrade reaction, or stiffness), and moisture condition. Research has identified additional considerations impacting the capacity and performance of ground anchors, including anchor geometry, anchor depth, anchor orientation, and direction of load relative to that orientation.

Soil response mechanisms are different for axially and non-axially loaded ground anchors. Soil response for axially loaded ground anchors is the result of shear stresses along the failure plane.

Figure 7-5. In line ground anchor installation.



Failure occurs when the stresses exceed the soil shear strength. The geometry of the failure surface varies based on the critical depth of the anchor. Ground anchors with an embedment depth less than the critical depth to anchor base width ratio ($(D/B)_{cr}$) respond as a shallow foundation. Ground anchors with a depth greater than $(D/B)_{cr}$ respond as a deep foundation.

Non-axially loaded ground anchors resist lateral movement by mobilizing the passive resistance of the surrounding soil. As small diameter rods develop little passive soil pressure resistance, stabilizer plates are used in the contact area to increase the passive resistance and reduce movement.

Figure 7-6 plots anchor load (in pounds) as a function of anchor head displacement (in inches), and shows the typical response for an anchor installed vertically and loaded axially. A test load of 6,000 pounds resulted in a movement of less than 2 inches. The graph also indicates that little or no movement occurred at loads less than about 225 pounds.

Vertical, axially loaded anchors are relatively efficient. The soil shear failure is a symmetrical, roughly truncated cone extended from the anchor bearing plate to the ground surface. Non-vertical, axially loaded ground anchors are somewhat less efficient due to the asymmetrical shape of the shear failure surface. The asymmetry is the result of the shallow depth at the top side of the anchor relative to the bottom side.

Movements of axially loaded anchors are proportional to the applied loads. The load-movement is approximately linear in granular or non-cohesive soils. Cohesive soils tend to be less linear, particularly as the amount of clay in the soil increases. Soil related anchor failure in granular soils may occur rapidly and may cause ground surface movements around the anchor. Anchors in cohesive soil typically fail more slowly.

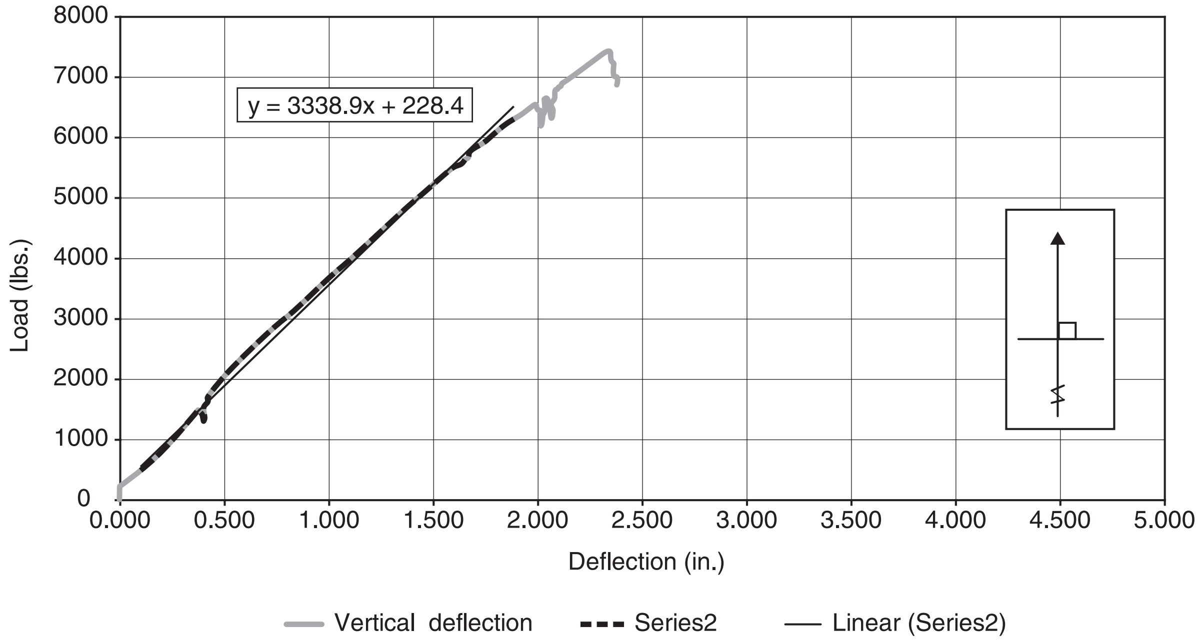


Figure 7-6. Typical response for an axially loaded anchor.

Anchor failure may also result from weld failure between the anchor shaft and the anchor head, weld failure between the shaft and the helix, collapsing of the anchor helix, or metal tearing around the anchor head strap bolts.

Anchors used with stabilizer plates respond differently than axially loaded anchors. Figure 7-7 shows the typical response for non-axially loaded anchors used with stabilizer plates. The small diameter shaft does not create much passive resistance in the soil; therefore, small loads produce relatively large movements. After the anchor shaft contacts the stabilizer plate, lateral movement as a function of load decreases significantly as a result of a larger area of passive resistance mobilized by the stabilizer plate. After the shaft contacts the stabilizer plate, stiffness, as indicated by the slope of the load vs. movement curve, increases significantly. However, the apparent stiffness, as indicated by the slope of the curve, remains less than axially loaded anchors.

For both axially and non-axially loaded anchors, the design stiffness should be selected to account for the variability of individual anchor performance during anchor tests, including an assessment of the upper limit of the applicability of the stiffness factor.

Shear strength in saturated soil is typically less than in non-saturated soils. Thus, anchors in saturated soils have a lower load capacity than non-saturated soils, and may exhibit decreased stiffness, especially in clays.

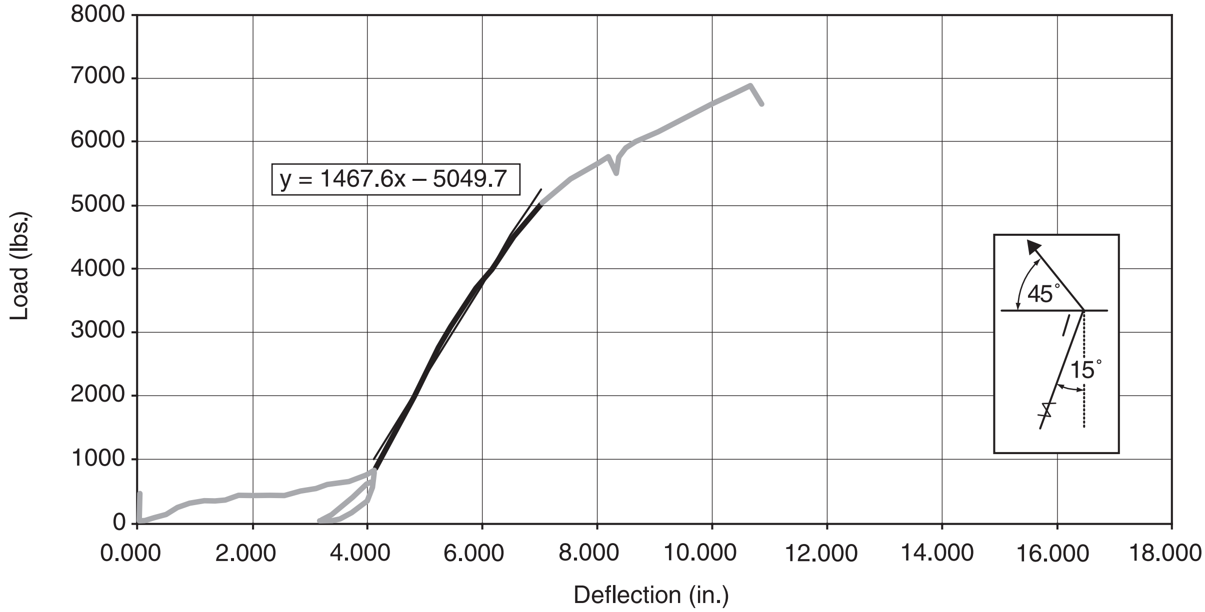


Figure 7-7. Typical response for a non-axially loaded anchor used with a stabilizer plate.

7.1.6 Anchors and Other Foundation Elements

Ground anchors are used with masonry piers, wood posts, or steel jack stands. For satisfactory performance, the piers, posts, and stands must function with relatively large displacements that the anchors may experience when subjected to flood, high-wind, or seismic loads. Large displacements are especially likely for non-axially loaded ground anchors. If subjected to relatively large movements, many foundation components cannot maintain their integrity. Piers, for example, can experience failure due to sliding of unmortared blocks or overturning of reinforced piers supported on ground surface pads (Figure 7-8).

7.2 FEMA Anchor Test Program

7.2.1 Anchors in Saturated Soils

Flooding can decrease soil shear strength and change the subsurface hydrostatic pressures as a result of an increase in the pressure gradient. The two mechanisms affect ground anchor performance differently. The effects are a function of soil characteristics, anchor end plate diameter, installation depth, and change in hydrostatic pressure. Research has indicated that, for a fixed depth, the ultimate capacity of screw anchors in dry sand is higher than screw anchors in submerged conditions. The impact of the reduction in capacity is significantly greater for shallow anchors than for deep anchors.

In 2002, FEMA participated in a field test program of 120 anchors to provide performance data for developing pre-engineered foundation designs using ground anchors. Sixty anchors were tested in a saturated site, and 60 anchors were tested in an adjacent dry site as a control group.

Figure 7-8. Failed foundation system that used masonry piers.

The results generally support the findings of previous research and have been used to develop the foundation designs included in this guide.

The tests were conducted by representatives from FEMA and its engineering consultants, HUD, the Manufactured Housing Institute (MHI), Florida Manufactured Housing Association (FMHA) and several ground anchor manufacturers (Tie Down Engineering, Oliver Technologies, Minute-Man, and Style Crest).

7.2.2 Anchor Test Results

Tables 7-2 and 7-3 contain the test results for dry site anchors and wet site anchors, respectively. Figure 7-9 shows three anchor configurations described in Tables 7-2 and 7-3. The data shown are for anchor stiffness or the amount of load the anchors develop per inch of anchor head movement. The data are raw data and are not indicative of design or working load values.

The data also include the standard deviations for the data groups. The data show that the performance of individual ground anchors varies significantly from the average performance of the group of anchors. This variance, or "spread" in ground anchor performance has a significant effect on appropriate design values. The greater the relative spread in individual anchor performance, the lower the appropriate design value.

Table 7-2. Dry Site Anchor Data

Anchor Style and Installation	Anchor Stiffness (pound/inch)			
	Min	Max	Average	Standard Deviation
5-foot anchor installed at 45° and loaded axially (Figure 7-9a)	1,505	3,283	2,426	543
5-foot anchor installed vertically and loaded axially (Figure 7-9c)	1,774	6,639	3,801	1,394
5-foot anchor installed 15° from vertical and used with an 11-inch by 17-inch stabilizer plate (Figure 7-9b)	1,006	2,001	1,475	294
4-foot anchor installed 15° from vertical and used with an 8-inch by 24-inch acrylonitrile butadiene styrene (ABS) stabilizer plate (Figure 7-9b)	1,019	2,612	1,721	497
4-foot anchor installed 15° from vertical and used with an 11-inch by 17-inch stabilizer plate (Figure 7-9b)	817	1,614	1,197	257

Table 7-3. Wet Site Anchor Data

Anchor Style and Installation*	Anchor Stiffness (pound/inch)			
	Min	Max	Average	Standard Deviation
5-foot anchor installed at 45° and loaded axially (Figure 7-9a)	2,874	9,019	5,506	1,829
5-foot anchor installed vertically and loaded axially (Figure 7-9c)	2,166	6,581	4,112	1,391
5-foot anchor installed 15° from vertical and used with an 11-inch by 17-inch stabilizer plate (Figure 7-9b)	833	1,412	1,094	193
4-foot anchor installed 15° from vertical and used with an 8-inch by 24-inch ABS stabilizer plate (Figure 7-9b)	655	2,006	1,538	370
4-foot anchor installed 15° from vertical and used with an 11-inch by 17-inch stabilizer plate (Figure 7-9b)	1,024	1,894	1,319	300

* See Figure 7-9.

Note that anchor stiffness values are based on the linear portion of the load deflection data. In most cases, the non-axially loaded anchors' significant movements occurred prior to reaching the linear response range. It should also be noted that the upper and lower limits of applicability of the stiffness values have not been fully evaluated. For axially loaded anchors in dry sand, the linear zone appears to exceed 6,000 pounds, about the limit of the test. Vertically loaded vertical anchors in wet sand had similar results; however, axially loaded anchors installed at 45 degrees in wet sand had an upper limit of about 4,500 to 5,000 pounds. Similar differences were observed for inclined anchors.

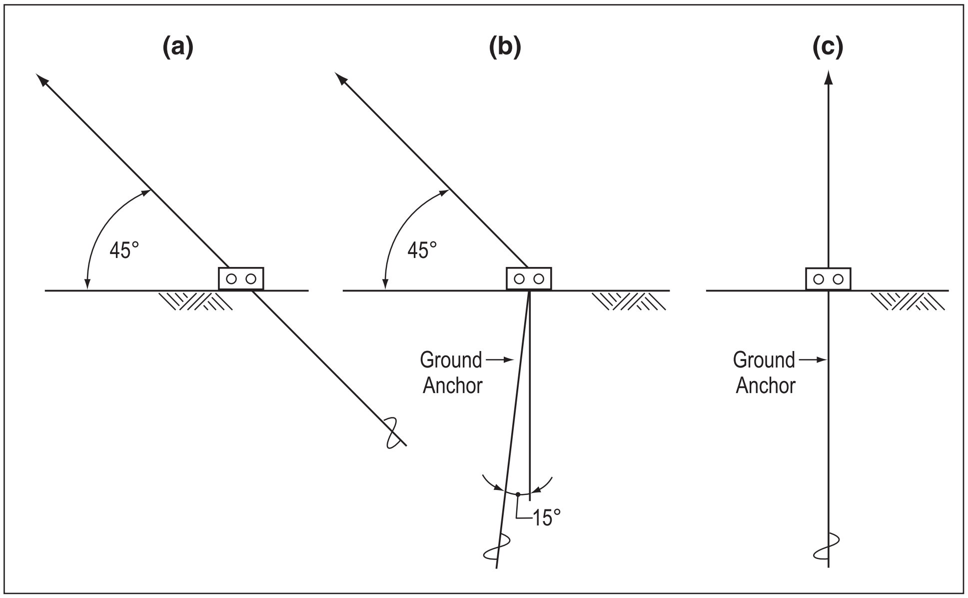


Figure 7-9. Three graphics showing the anchor configurations described in Tables 7-2 and 7-3. From left to right, they are (a) ground anchor installed at 45 degrees and loaded axially, (b) ground anchor installed at 15 degrees from vertical and loaded 45 degrees from horizontal, and (c) ground anchor installed vertically and loaded axially.

7.3 Recommended Ground Anchor Certification, Performance, and Design Values

7.3.1 Recommended Ground Anchor Certification Performance

Currently, there is no consensus based standard protocol for certifying ground anchors used to anchor manufactured homes. Some States have developed certification procedures and a task group under HUD's Manufactured Housing Consensus Committee (MHCC) has been working on a Ground Anchor Test Protocol (GATP) for certifying ground anchors. Although no standard protocol had been completed at the time this guide was published, the ground anchor design strengths included in this guide assume that the ground anchors will achieve a level of performance that can be relied upon to anchor the home and resist applied loads from a design event.

7.3.2 Recommended Ground Anchor Design Values

The following data present recommended ground anchor design values for use when ground anchors have not been load tested or otherwise certified for a specific capacity. The information, while limited, is based on the best available data from the FEMA ground anchor testing program. FEMA's testing program gathered data on ground anchor performance and soil saturation effects, and was conducted on sandy Class 4b soils.

The recommended design loads contained in Table 7-4 were developed by applying the statistical factors required to produce a design load that provides a 10 percent lower exclusion limit with a 90 percent confidence level. The factors were applied to the FEMA test data.

Table 7-4. Recommended Design Loads – from FEMA Ground Anchor Testing Program

Anchor Style and Installation – FEMA Tests	Recommended Design Load (pounds)
5-foot anchor installed at 45°and loaded axially	3,150
5-foot anchor installed vertically and loaded axially	3,000
5-foot anchor used with an 11-inch by 17-inch stabilizer plate	2,000
4-foot anchor with an 8-inch by 24-inch ABS stabilizer plate	2,000
4-foot anchor used with an 11-inch by 17-inch stabilizer plate	2,000

Recommended design stiffness values were selected that provide a 90 percent confidence level; this means that no more than 10 percent of individual anchors would provide resistances less than design values. This level of statistical performance is less conservative, but similar to statistical performance levels applied to other structural materials like steel or concrete.

The lowest stiffness values from the dry and wet sites were selected for design. Generally, the dry site values controlled for axial pull anchors while the saturated site anchor values controlled for anchors using stabilizer plates. Table 7-5 lists the recommended design stiffness for the anchors tested.

Table 7-5. Recommended Design Stiffness for Tested Anchors

Anchor Style and Installation	Anchor Design Stiffness (pound/inch)	Controlling Soils
5-foot anchor installed at 45° and loaded axially	1,200	dry
5-foot anchor installed vertically and loaded axially	1,010	dry
5-foot anchor used with an 11-inch by 17-inch stabilizer plate	675	wet
4-foot anchor with an 8-inch by 24-inch ABS stabilizer plate	708	wet
4-foot anchor used with an 11-inch by 17-inch stabilizer plate	659	wet

With a 3-inch displacement, the axially loaded anchors provide working loads greater than the 3,150-pound loads required by HUD (e.g., 1,200 pounds/inch x 3 inches = 3,600 pounds). However, the anchors with stabilizer plates provide only about two-thirds of the HUD required capacity. The anchor stiffness values in Table 7-5 are based on the linear portion of the load-deflection curve. Designers need to evaluate potential deflections at loads below the linear range, particularly for inclined anchors loaded non-axially.

7.4 Ground Anchors in Seismically Active Areas

While data exist on the performance of ground anchors in static saturated soils, no definitive testing has been completed that predicts how ground anchors will perform in saturated soils during a seismic event. Seismic events can result in soil liquefaction, particularly in fine sands like those in the test program. Liquefaction may result in a significant and potentially total loss of anchor capacity during a seismic event. A registered engineer should be consulted to evaluate the liquefaction potential at the proposed manufactured home installation site.